THE BAFCO 916XH AT THE ALLEN-BRADLEY COMPANY

Here is a bit of history from my time with the Bafco 916XH Frequency Response Analyzer.

As a development engineer at Allen-Bradley, Milwaukee, a few years out of school from Ohio State in the late 1970's, our Engineering Director decided that the Milwaukee operation should develop a Programmable Logic Controller (PLC) much smaller than the big iron being designed and sold by our Cleveland A-B group who, along with a few earlier companies had pioneered the PLC concept.

The internal political turf battle between the Milwaukee and Cleveland divisions was raging while a few of us designed the Bul. 1742 MAC Modular Automation Controller, the forerunner of the small PLC's that followed from Milwaukee, like the SLC-100 series and many others to this day.

The history of switching power supply design within A-B at the time left room for a more reliable approach which dictated what I used for the MAC.

The application was the typical industrial control panel with a transformer that took single phase 480VAC from the plant overhead 3-phase bus bars and dropped it down to 120VAC, then rectified and filtered and fed to a DC-DC converter to produce 5VDC at about 3 Amps to run the 8051 and associated circuitry.

The design was nothing exotic but designed and built like a tank and it kept the product from being abused in the industry by electricians who would wire things up in unimaginable ways, destroying the PLC and giving A-B field problems. And it avoided blowing up off-line switching transistors like the SMPS from Cleveland that gave power supplies a bad reputation within the company – I actually had to present the design approach to the President of our group and assure him Milwaukee would not replicate the experience Cleveland suffered.

I chose a new DC/DC PWM converter part in a TO-3 can from Lambda Semiconductor and armed with all the IEEE papers I could find from Dr Middlebrook and Dean Venable, I proceeded to design the circuit.

I had taken one grad school course in Control Theory at Ohio State (D'Azzo and Houpis' text) in 1977 and loved what I learned.

It had brought to life the Servo Loop tests we had run as Missile Technicians on the Thrust Vector Control systems of the Polaris A-2 missiles on our submarine in the US Navy prior to my discharge and returning to school at OSU.

We routinely ran the loop tests out on patrol during the Cold War to make sure the TVC systems were working properly - I will never forget the screaming sound of the motors that threw the rocket motor nozzles all over the place during the test.

We had to open the Lower-Level access hatch to the missile's first stage rocket motors and observe the nozzles as the test was run. The first-stage thrust vector control (TVC) on the Polaris A-2 missile used hydraulic drives to manage the nozzle positioning. The Aerojet-designed first stage featured four nozzles equipped with ring deflectors (jetevators). These deflectors were mechanically articulated by compact, high-pressure hydraulic actuators that received steering commands from the General Electric/MIT inertial guidance system.

So closed loops became part of my nature as a Missile Technician and once I got the chance to study the math behind control theory it all made sense.

Our use of the Bode plot at OSU was very informative and I felt comfortable with them so when it came time to design my converter, I figured I would need to use the tool, but how was I to measure what I had designed to see if I had the magic 45-degree phase margin I was supposed to achieve - the figure that cropped up in all the texts of the time?

I came across the Bafco 916XH Frequency Response Analyzer and convinced my boss and our department manager that we needed one - which turned out to be easy since both were controls engineers and understood what I was talking about, but in their time had never seen one.

The engineers at Lambda suggested I use a Type III compensation network, and I had figured out that rather than use the transconductance amplifier in the Lambda part I would go with an outboard op-amp, the venerable LM324N, and wrapped my compensation network around it.

The Type III network looked great, but I had no idea which part did what – which combination of parts created which poles and zeroes, and what about that output cap's ESR?

I then proceeded to write the LaPlace equations for the transfer function of the converter from the output filter down through the dropping resistors and through the op-amp compensation network.

After pages and pages of pencil calculations I finally wrestled them into linear control theory's canonical form and out popped the exact equations for each of the poles and zeroes in terms of all the R's and C's. Remember, it was 1978…

Eureka!!

Although by visual inspection of the circuit I could make no sense of which combinations of R's and C's were contributing to the various poles and zeroes, the equations made it clear

which ones combined for the intended purpose. It was not intuitive at all when you considered where they were on the Bode plot until I did the calculations.

The Bafco was my friend from then on - and the light that LaPlace shed on the circuit was a big help.

The look on my section manager's face when I brought him the X-Y plotter prints of the loop gain and phase was priceless – he was seeing things he had only dreamed about in his career.

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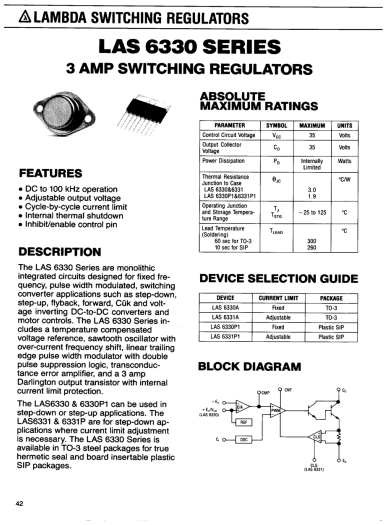

LAMBDA SWITCHING REGULATORS

LAS 6330 SERIES

3 AMP SWITCHING REGULATORS

FEATURES

- DC to 100 kHz operation
- Adjustable output voltage
- Cycle-by-cycle current limit
- Internal thermal shutdown
- Inhibit/enable control pin

DESCRIPTION

The LAS 6330 Series are monolithic integrated circuits designed for fixed frequency, pulse width modulated, switching converter applications such as step-down, step-up, flyback, forward, Cük and voltage inverting DC-to-DC converters and motor controls. The LAS 6330 Series includes a temperature compensated voltage reference, sawtooth oscillator with over-current frequency shift, linear trailing edge pulse width modulator with double pulse suppression logic, transconductance error amplifier, and a 3 amp Darlington output transistor with internal current limit protection.

The LAS6330 & 6330P1 can be used in step-down or step-up applications. The LAS6331 & 6331P are for step-down applications where current limit adjustment is necessary. The LAS 6330 Series is available in TO-3 steel packages for true hermetic seal and board insertable plastic SIP packages.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	MAXIMUM	UNITS
Control Circuit Voltage	V_{CC}	35	Volts
Output Collector Voltage	C_O	35	Volts
Power Dissipation	P_D	Internally Limited	Watts
Thermal Resistance Junction to Case LAS 6330&633 LAS 6330P1&6331P1	θ_{JC}	3.0 1.9	°C/W
Operating Junction and Storage Temperature Range	T_J T_{STG}	– 25 to 125	°C
Lead Temperature (Soldering) 60 sec for TO-3 10 sec for SIP	T_{LEAD}	300 260	°C

DEVICE SELECTION GUIDE

DEVICE	CURRENT LIMIT	PACKAGE
LAS 6330A	Fixed	TO-3
LAS 6331A	Adjustable	TO-3
LAS 6330P1	Fixed	Plastic SIP
LAS 6331P1	Adjustable	Plastic SIP

BLOCK DIAGRAM

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